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ABSTRACT

Problem-Based Learning (PBL) describes a learning environment in which problems drive the learning; that is, learning begins with a problem to be solved and the problem is posed in such a way that students need to gain new knowledge before they can solve it. This ERIC Digest discusses many aspects of PBL including a brief history, implementing PBL, modifying traditional instructional approaches to include PBL, and web resources. (MVL)

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Problem-Based Learning in Science

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Problem-based learning (PBL) is an instructional approach that challenges students to seek solutions to real-world (open-ended) problems by themselves or in groups, rather than learn primarily through lectures or textbooks. More importantly, PBL engages students in developing skills as self-directed learners. Problems are selected to exploit natural curiosity by connecting learning to students' daily lives and emphasizing the use of critical and analytical thinking skills.

According to Gallagher (1997), the primary goal of PBL is characterized as learning for capability rather than leaning to acquire knowledge. The effectiveness of PBL depends on the nature of student engagement and the culture of the classroom, as well as the appropriateness of the problem tasks assigned. Proponents of PBL believe that when students develop their own problem-solving procedures, they are integrating their conceptual knowledge with their procedural skills.

Having its origins in the medical field, PBL is an effective and practical way of training physicians. Medical students engaged in PBL are more successful than traditionally prepared students with respect to problem-solving, self-evaluation, data gathering, other learning skills (Albanese & Mitchell, 1993).

Although PBL meshes well with constructivist views of learning, it did not emerge in response to educational theory (White, 2001). PBL provides students with opportunities to direct their own learning while developing critical thinking and evaluation skills through analysis of real life problems (Smith, 1995). Smith characterized the advantages of PBL this way:

> PBL's proponents emphasize that it improves thinking and learning skills and cognitive abilities in students. It has been reported that PBL-trained students are more frequent users of libraries and other information resources, which support independent learning. They acquire life long study skills, especially in their early years of study, giving rise to sustained learning...PBL educated students have a more holistic approach to their subject, more readily integrate new information, adapt to change and work well as member of a team. Generally PBL appears to increase student interest and enjoyment to the subject and enhance their professional development (p. 150).

Research indicates that the increased success of students involved in PBL is based on the ability of PBL to activate prior knowledge more effectively; increased elaboration of information that promotes mental processing, greater understanding, and recall; and learning in a context that resembles real-world situations (Jones, 1996b). Research also indicates that PBL supports and enhances student information gathering skills and retention through implementation of basic and clinical sciences, where student knowledge, interests, and motivation are increased (Finucane, Johnson, & Prideaux, 1998). Additional advantages of PBL are identified online at: http://edweb.sdsu.edu/clrit/learningtree/PBL/PBLadvantages.html

Implementing PBL

According to the *National Science Education Standards* (National Research Council, 1996), a major goal of science education is to develop scientifically literate citizens who can function in their adult stages with skills necessary for life long learning. In a PBL approach to instruction, the teacher attempts to catalyze student learning through critical thinking and an increased ability to seek and find information related to problem situations. Student learning in this context results in part through collaboration, self-directed learning, and solution of authentic problem situations (Barrows, 1997)

Greenwald (2000) listed the following 10 steps of PBL based on a medical school model:

1. Encounter an ill-defined problem; an ill-defined problem is the backbone of PBL. Greenwald (2000) characterized an ill-define problem as being "unclear and raises questions about what is known, what needs to be known, and how the answer can be found. Because the problem is unclear, there are many ways to solve it, and the solutions are influenced by one's vantage point and experience" (p. 28). An ill-defined problem can be introduced to students within the context of a larger, realistic scenario.
2. Ask questions about what is interesting, puzzling, or important to find out in relation to the problem. By asking students open-ended questions, a discussion environment can be created for considering the interesting observations.
3. Pursue various problem-finding strategies. Different problem-finding strategies for identifying and clarifying problems can be offered by the teacher in this process.
4. Map problem-finding activities and prioritize a problem. In this step students reorganize the problems they identify in the previous step and explain the relationship patterns among their ideas.
5. Investigate the problem. Inquiry guided questions can be used to help students strategize and plan their investigations.
6. Analyze results. With guiding questions students analyze their results.
7. Reiterate learning. This is a distinguished feature of the PBL approach where students present what they have learned to their peers.
8. Generate solutions and recommendations. By revisiting the analysis and reiteration steps, students generate solution ideas and recommendations.
9. Communicate the results. Students communicate to the

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teacher and others what they have learned based on the roles they have played in the problem solving process.

10. Conduct self-assessment. Authentic assessment strategies can be used for students who present group findings, problem solving, knowledge acquisitions, and self-directed and collaborative learning skills.

The Challenge

Modifying traditional instructional approaches and implementing new methods are often difficult tasks for teachers, and incorporating PBL is no exception. Along with the advantages of PBL come disadvantages and limitations, and these have been grouped into six categories by Jones (1996a): academic achievement, amount of instructional time required, role of students, role of teachers, appropriateness of problems, and appropriate assessment of student performance.

Jones (1996a) emphasized that generating proper questions is the most critical aspect of PBL. Further, Jones stressed the importance of appropriate assessment of student performance. Standardized tests are usually designed to assess the academic achievement of students who have learned through traditional instruction, but PBL differs from traditional instruction in a variety of ways. More appropriate assessment methods would include written examinations or reports, practical examinations, construction of concept maps, peer assessment, self assessment, or oral presentations.

According to Ngeow and Kong (2001), students engaged in PBL become more responsible for their own learning, but the transition to self-directed learning can be difficult for some. Group-based learning is also integral to PBL, and students must learn to function effectively in groups.

Costs and resistance to change among educators are other limitations to PBL that must be addressed through professional development of teachers (Dempsey, 2002; Smith, 1995). The role of teachers in PBL is to serve as mentors once a problem has been introduced to students, so teachers must learn to communicate with students at the metacognitive level, facilitating reasoning by asking questions and not giving too much information (Putnam, 2002).

Web Resources

IMSA Center for Problem-Based Learning
http://www.imsa.edu/team/cpbl/cpbl.html

Access Excellence Mystery Spot
http://www.accessexcellence.org/AE/mspot/
Interactive, online scientific mysteries designed to encourage student problem-solving and inquiry.

UBUYACAR
http://www.mcli.dist.maricopa.edu/pbl/ubuytutor/index.html
Materials and directions for implementing a PBLproject based on buying a car.

Learning Matrix
http://thelearningmatrix.enc.org/
Part of the NSF-funded National Digital Library Initiative, this site provides access to peer-reviewed digital resources that promote inquiry and problem-based learning in college mathematics, science, and technology classes.

PBL Clearinghouse
https://www.mis4.udel.edu/Pbl/
A collection of peer-reviewed problems and articles to assist educators in using problem-based learning. Teaching notes and supplemental materials accompany each problem, providing insights and strategies that are innovative and classroom-tested. Access is limited to educators who register via an online application, but is free and carries no obligation.

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